Introduction to Computer Vision
Lecturers:

- prof. Ender Konukoglu
- prof. Luc Van Gool
- prof. Fisher Yu
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The course comes with a course text that covers most – but not all! – material. **Slide decks** for all lectures will be made available and are the actual reference for study.
We got questions about which course to take

*Computer Vision (D-INFK), or Image Analysis and Computer vision* (this course)

**IN ANY CASE, DO NOT TAKE BOTH!**

If you took the introductory course on CV at D-INFK, then best take *Computer Vision*

If you did not take that course, then best take *Image Analysis and Computer Vision*
This introductory lecture:

1. human perception
2. applications
3. light
This introductory lecture:

1. human perception
2. applications
3. light
Vision is important

- half our brain is devoted to it
- developed multiple times during evolution
- it is non-contact
- it can be implemented with high resolution
- works with ambient E-M waves
- yields colour, texture, depth, motion, shape
The central take-home message:

For people vision is the most important sense, for good reason
The perception of intensity
The perception of color

The balls all have the same color...
The perception of color

The balls all have the same color…
The perception of length

A

B

C
The perception of length

The horizontal lines are equally long...
The perception of lines being straight
The perception of parallelism
The perception of curvatures

Illusions: interference of differently oriented patterns via adaptation
The perception of motion

The `barber pole' rotates about the vertical, it does not translate vertically…
It’s not that more context solves it all…

there is literally more than meets the eye, i.e. a lot of massively parallel processing
The perception of intensity
The brain factors out illumination

Checker-shadow illusion: The squares marked A and B are the same shade of gray.
Computer Vision

INTRO

perception
applications
light
Parallelism again…
Kanisza illusion

Fill-in: averaging of perceived contrast at edges over regions possibly obtained via extrapolation of the edges… in any case such illusion seems to help people to detect patterns in the world.
The role of context

Human vision: Biederman, Bar & Ullman, Palmer, ...

perception
applications
light
The role of context

All encircled patterns are identical:
The role of context
The role of context
The role of context
The role of context
The role of context

human vision is much more than a bottom-up process of subsequent signal processing steps.
The central take-home message:

**Effective vision needs more than sheer filtering and measuring**
This introductory lecture:

1. human perception
2. applications
3. light
The explosion of photography

![Graph showing the growth of billions of photos per year from 1800 to 2000. The graph compares all photos and analog photos, with a significant increase starting around 1970.](image)
Easier than ever to take a photo
The cost is extremely low (cheap memory)
Most people carry a camera most of the time
The development of computer vision apps

Most early applications were found in production environments, as these *allow for controlled conditions* and *have little uncertainty*.

Some areas do not allow for much control: medical IP, remote sensing, surveillance, etc., and became somewhat independent areas of specialization.

Currently CV is *conquering other less controllable areas* by storm.
Ex App: image enhancement: mobile -> DSLR
Ex App: synthetic face generation

https://miro.medium.com/max/1176/1*LZp9nkzbSk8v6cpwp8CD8g.gif
Ex App: autonomous vehicles
Ex App: autonomous vehicles

car detection:
Ex App: autonomous vehicles

putting vision modalities together:
Ex: autonomous mobile platform
Ex App: image retrieval, captioning, ...

- A person riding a motorcycle on a dirt road.
- Two dogs play in the grass.
- A skateboarder does a trick on a ramp.
- A dog is jumping to catch a frisbee.
- A group of young people playing a game of frisbee.
- Two hockey players are fighting over the puck.
- A little girl in a pink hat is blowing bubbles.
- A refrigerator filled with lots of food and drinks.
- A herd of elephants walking across a dry grass field.
- A close up of a cat laying on a couch.
- A red motorcycle parked on the side of the road.
- A yellow school bus parked in a parking lot.
Ex App: visual surveillance
Ex App: Augm. Reality, eg sports

Virtual Overlay

Virtual Insert

Nice Virtual Advertising by uniqFEED

Original

Broadcast to the world – reach the individual®
Computer Vision

Ex App: motion capture for movies/games
Ex App: computer-assisted surgery
Ex App: mobile mapping
The central take-home message:

It is feasible now to let most things see and interpret their environment
This introductory lecture:

1. human perception
2. applications
3. light
And then there was Light…

- no vision without light…
- … because it is influenced by objects

"What the...?"
Kickoff: the light, surface, lens & cam
Kickoff: the light, surface, lens & cam
topics

- the nature of light
- interactions with matter
Levels of optical analysis

1. Geometrical optics

2. Physical optics, or

3. Quantum-mechanical optics

wave character
Light as electromagnetic waves
Light as electromagnetic waves

Self-sustaining exchange of electric and magnetic fields

1. wavelength
2. direction
3. amplitude $E$
4. phase
5. direction of polarisation
The spectrum

Normal ambient light is a mixture of wavelengths, polarisation directions, and phases
The visible range of wavelengths

<table>
<thead>
<tr>
<th>Wavelength (in nm)</th>
<th>Colour</th>
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<tbody>
<tr>
<td>380 - 450</td>
<td>violet</td>
</tr>
<tr>
<td>450 - 490</td>
<td>blue</td>
</tr>
<tr>
<td>490 - 560</td>
<td>green</td>
</tr>
<tr>
<td>560 - 590</td>
<td>yellow</td>
</tr>
<tr>
<td>590 - 630</td>
<td>orange</td>
</tr>
<tr>
<td>630 - 760</td>
<td>red</td>
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**NOTE 1:** From the observed colour you must not conclude that the light only contains wavelengths as given on the left.

**NOTE 2:** Cameras may have different spectral sensitivities (i.e. also different from human vision)
NOTE 3: animals may have different spectral sensitivities (i.e. different from human vision), and may also have a different number of cone types (see lecture on colour), like 4 in most birds.
Also cams for non-visible `light’, e.g. infrared

Overheating of transformer coils, with far IR

Near infra-red (NIR) space image

NGR -> RGB for visualization (notice the strong reflection in the NIR for vegetation)
Interactions with matter

four types:

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+ diffraction
## Interactions with matter

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+ diffraction
Scattering

3 types depending on relative sizes of particles and wavelengths:

1. small particles: *Rayleigh* (strongly wavelength dependent)
2. comparable sizes: *Mie* (weakly wavelength dependent)
3. Large particles: *non-selective* (wavelength independent)
Wavelength dependence

Less haze in the infrared (long wavelengths -> little scatter)
Looking through clouds by radar (even longer wavelengths)
NOTE: without scatter we would wander mainly in the dark
Atmospheric showcase

**Rayleigh:**
Tyndall effect (blue sky)
Red, setting sun

**Non-selective:**
Grey clouds

**Mie:**
Coloured cloud from volcanic eruption

INTRO
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**Interactions with matter**

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+ diffraction
Mirror reflection
Mirror reflection

Angle of reflection = angle of incidence
Mirror reflection: dielectric

Polarizer at *Brewster angle*

Full reflection at grazing angles
Mirror reflection: conductor

strong reflectors (under all angles) more or less preserve polarization
Roughness of surfaces leads to `diffuse’ reflection

(a) Mirror or `specular’ reflection,  (b) diffuse reflection
... and to mixed reflection for most real surfaces

three types of reflection:

- diffuse
- specular
- mixed

Note: Lambertian example of diffuse reflection.

Under Lambertian reflection the surface looks equally bright when viewed from any direction
Spectral reflectance e.g. vegetation

![Graph showing spectral reflectance with wavelengths on the x-axis and reflectance on the y-axis. The graph compares upper and lower leaf sides.](image-url)
Interactions with matter

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+ diffraction
Refraction
Refraction

\[ n_1 \sin \theta_i = n_2 \sin \theta_t \]

Snell’s law
Dispersion

Refraction is more complicated than mirror reflection: the path orientation of light rays is changed depending on material AND wavelength  !!!
### Interactions with matter

There are four types of interactions:

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Absorption

Dissipation of wavelengths specific for the medium

Based on resonance frequencies of molecules -> peaks
Holes in sky light spectrum observed by Fraunhofer
The solar spectrum

Peaks around 500nm, hence human sensitivity for that part of the spectrum

Spectral composition of light above atmosphere

Spectral composition of light below atmosphere

... some wavelengths get strongly weakened due to absorption